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SEMINARS IN MUSCULOSKELETAL RADIOLOGY VOLUME 4, NUMBER 1 2000

Primary Musculoskeletal Tumors of Fibrous Origin

Stacy E. Smith, M.D.,‡ and Mark J. Kransdorf, M.D.*†*

ABSTRACT

Tumors of fibrous origin include fibrous dysplasia (FD), fibroxanthoma (nonossifying fibroma), cortical desmoid, desmoplastic fibroma, fibrosarcoma, and malignant fibrous histiocytosis (MFH). Benign fibrous lesions (FD, fibroxanthoma, and cortical desmoid) frequently demonstrate pathognomonic radiologic characteristics obviating the need for biopsy. Indeed, biopsy of these lesions can occasionally lead to confusion with more aggressive lesions. Desmoplastic fibroma and the malignant fibrous lesions (fibrosarcoma and MFH) often reveal nonspecific imaging features of a solitary nonmineralized lesion with aggressive characteristics. However, imaging is important as with other neoplasms in delineating the extent of involvement for staging purposes. This article reviews the spectrum of clinical characteristics, pathology, imaging appearances, treatment, and prognosis of lesions of fibrous origin in bone.

KEYWORDS: Fibroxanthoma; cortical desmoid; desmoplastic fibroma; malignant fibrous histiocytoma; fibrosarcoma, fibrous dysplasia

FIBROUS DYSPLASIA

Rather than being a true neoplasm, fibrous dysplasia (FD) is a developmental anomaly of bone in which the normal medullary space is replaced by fibroosseous tissue.[1] FD is relatively common, typically seen in young adults and adolescents. The clinical presentation is quite variable: It may be localized to a single bone (monostotic fibrous dysplasia, 70 to 85%) or multiple bones (polyostotic fibrous dysplasia, 15 to 30%). Approximately 30 to 50% of patients with polyostotic disease will also have patches of cutaneous pigmentation, with irregular serrated margins (cafe-au-lait spots).[1–3]

Endocrine dysfunction has been described in association with FD. The classical association is McCune-Albright syndrome, which consists of the triad of polyostotic FD (typically unilateral), cutaneous café-au-lait spots (usually ipsilateral to the bone lesions), and endocrine dysfunction (especially precocious puberty in girls).[4] This syndrome occurs in 30 to 40% of females with polyostotic fibrous dysplasia. However, manifestation of the complete triad is unusual (3 to 4%).[1] Multiple additional endocrinopathies can also occur in polyostotic FD all related to the basic hypothalamic dysfunction and include hyperthyroidism, hyperparathyroidism, diabetes mellitus, and Cushing disease. Skeletal fibrous dysplasia coexistent with soft tissue myxoma has also been reported. Typically seen with polyostotic disease, this association, known as Mazabraud syndrome, is rare.[5,6]

Lichtenstein introduced the term *FD* into the medical literature in 1938 and reported eight cases.[7] In 1942, Lichtenstein and Jaffe reviewed the existing literature on 75 previously reported cases of FD and added 15 cases of their own, establishing it as a distinct entity.[8,9] Microscopically, FD is composed of fibrous tissue containing bone trabeculae.[1,2] The stroma is a myxofibrous tissue of low vascularity, whereas the bone trabeculae are composed of woven bone (Fig. 1).[3] The contour of the trabeculae vary from solid, round islands to a wide variety of curved, serpentine, or curlicue shapes that have

*Department of Radiologic Pathology, Armed Forces Institute of Pathology, Washington, DC, and ‡Department of Diagnostic Imaging, University of Maryland School of Medicine, Baltimore, Maryland; and †Department of Radiology, St. Mary's Hospital, Richmond, Virginia

Reprint requests: Dr. Smith, Department of Radiologic Pathology, Armed Forces Institute of Pathology, 14th St. and Alaska Avenue, Washington, DC 20306-6000

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Figure 1. High-power photomicrograph (225×; hematoxylin-eosin stain) shows the characteristic appearance of fibrous dysplasia with fibrous stroma and woven bone. Woven bone demonstrates a varied appearance. Well-formed bone is seen on left of the field, with more poorly formed bone on the right. Note the curved, serpiginous, and curlicue shapes, likened to Chinese characters.

been likened to Chinese characters or English letters (alphabet soup).[3] Hemorrhage and cystic change may occasionally be found and rare cases have overt secondary changes resembling those of an aneurysmal bone cyst, which can mimic sarcomatous transformation (clinically and radiologically).[3]

CLINICAL CHARACTERISTICS

Patients afflicted with FD are typically young, in the first and second decades of life,[3] with 75% presenting before the age of 30 years.[1,10] Patients with small lesions may be asymptomatic, with the osseous abnormality identified incidentally. Symptoms, when present, are nonspecific and include pain, swelling, tenderness, and stress or overt pathologic fracture.[3] Patients affected by polyostotic FD typically present much earlier in life (67% by age 10 years) with a mean age of 8 years[3] and symptoms of pain, limp, or pathologic fracture.[11] Harris et al[11] reported abnormal vaginal bleeding as the presenting complaint in 25% female patients with polyostotic FD, related to precocious puberty.

Overall, males and females are affected equally, although some series show significant variance to this.[1–3] Any bone within the skeleton can be affected. The most common sites of skeletal involvement in monostotic FD are the ribs (28%), proximal femora (23%), and craniofacial bones (20%).[3] In polyostotic FD, the spectrum of involvement varies from two bones to more than 75% of the skeleton, with Harris et al reporting that more than 50% of the skeleton was affected in six of 26 patients evaluated with skeletal survey.[11] Polyostotic FD is most commonly found in the craniofacial area (50%), femur (91%), tibia (81%), pelvis (78%), and foot (73%). Unusual sites to be involved include the hands, spine, and clavicles.[11] Severe skeletal involvement may be associated with marked deformity, disability, and pathologic fractures in as many as 85% of these patients.[1,11] Fibrous dysplasia may be exacerbated by pregnancy, demonstrating increased biological activity resulting in lesion enlargement, pain, pathological fracture, and aneurysmal bone cyst formation.[10,12,13]

RADIOLOGIC FEATURES

Fibrous dysplasia demonstrates a wide spectrum of radiologic appearances. However, radiographs are often sufficiently characteristic for diagnosis. Radiographs reveal a lesion centered in the diametaphyseal region of the medullary space, underscoring the fundamental pathophysiology of FD as a process in which normal marrow is replaced by fibro-osseous tissue. Lesions may be eccentric but do not arise from the cortex. A similar lesion arising in the cortex is referred to as osteofibrous dysplasia and almost always affects the tibia and is a separate and distinct entity with a different clinical presentation and natural history.

Lesions often cause endosteal scalloping of the cortex, which may be diffusely thinned, with bone remodeling, secondary to the enlarging mass of fibro-osseous tissue. The lesion may be surrounded by a rind of thick, sclerotic reactive bone.[14] This sclerotic margin can be of variable thickness, may be interrupted or incomplete, and is often a prominent feature in monostotic lesions (Fig. 2). Lesions without sclerosis are also typically sharply marginated.[14] Less frequently the lesion will show a multiloculated

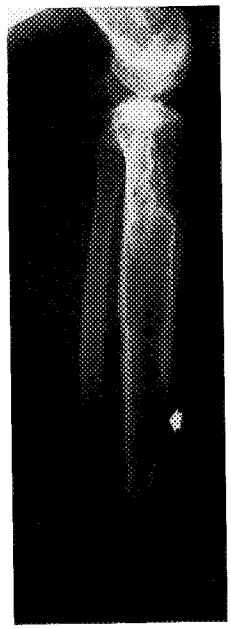


Figure 2. Fibrous dysplasia of the tibia in a 27-year-old man. The lesion has caused endosteal scalloping (arrow) and is surrounded by a thick rind of sclerotic bone.

appearance due to subperiosteal bone reinforcement along preexisting trabeculae.[14]

Periosteal reaction is not seen in the absence of pathological fracture or malignant transformation. The fibro-osseous tissue within the lesion imparts a characteristic opacity to the bone ("ground glass"), resulting from the delicate closely meshed spicules of bone.[3] The amount of woven bone, and the extent to which it is mineralized, ultimately determines the radiographic density of the lesion (Fig. 3). Rarely, FD may contain islands of cartilage that may undergo mineralization and enchondral bone formation, resulting in foci of dense punctate or flocculent calcifications.[15] This combination of enchondroma within FD, sometimes referred to as fibrocartilaginous or osteocartilaginous FD, is encountered most frequently in the proximal femur.[15]

Craniofacial involvement is common in the frontal, sphenoid, maxillary, and ethmoid regions. These lesions are frequently associated with craniofacial deformity, including neurologic deficits. FD of the calvarium often causes widening of the diploic space with much more prominently expansile remodeling of the outer table. Lesions frequently reveal the typical ground glass appearance radiologically. However, sclerosis is common in craniofacial involvement by FD, particularly in the skull base.

Lesions vary in size from a small, focal abnormality to a large lesion, involving most or all of a long bone (Fig. 4). Epiphyseal involvement is unusual particularly before closure of the growth plate. Isolated epiphyseal involvement is rare.[14,16] Certain patterns of bone involvement are characteristic of FD. Involvement in the proximal femur can result in a marked varus deformity (shepherd's crook deformity) probably resulting from abnormal bone modeling from alteration of normal biomechanical properties (Fig. 5).[14]

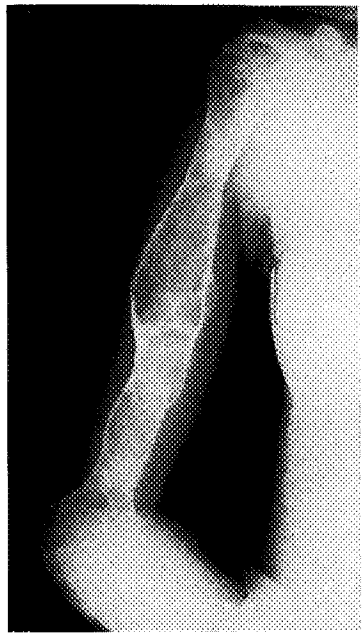


Figure 4. Fibrous dysplasia of the humerus in a 26-year-old woman. Anteroposterior radiograph shows the lesion extending almost the entire length of the humerus with a multiloculated trabeculated appearance and expanded, remodeled contour.

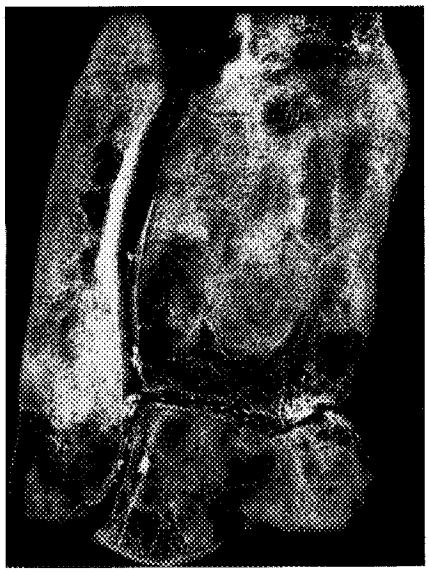


Figure 3. Polyostotic fibrous dysplasia. Specimen radiograph shows the fibro-osseous tissue replacing the normal marrow. Note expanded, remodeled contour of the bone as well as thinning of the overlying cortex. Areas in which there are a greater number of trabeculae are more radioopaque, whereas those with less trabeculae are more radiolucent.

Bone scintigraphy of patients with FD typically exhibits markedly increased radionuclide accumulation on delayed imaging although there is probably more variability than has been reported (Fig. 6).[17,18] Early perfusion imaging has also been reported to demonstrate markedly increased tracer uptake; however, our experience has been that flow and blood pool images often show only mildly increased tracer accumulation. Scintigraphy remains the best method for identification of the extent of skeletal involvement, particularly those with polyostotic disease.[17]

Computed tomography (CT) accurately delineates the extent of skeletal involvement and may be especially useful in evaluating craniofacial lesions or those suspected of having undergone sarcomatous transformation.[14,19,20] We have also found CT a valuable adjunct for evaluation of FD lesions not well seen on radiographs, such as those in which the osseous anatomy is complex (spine, skull, and pelvis). Areas of ossification within the lesion may have high attenuation and nonmineralized regions similar attenuation as muscle.[14,19]

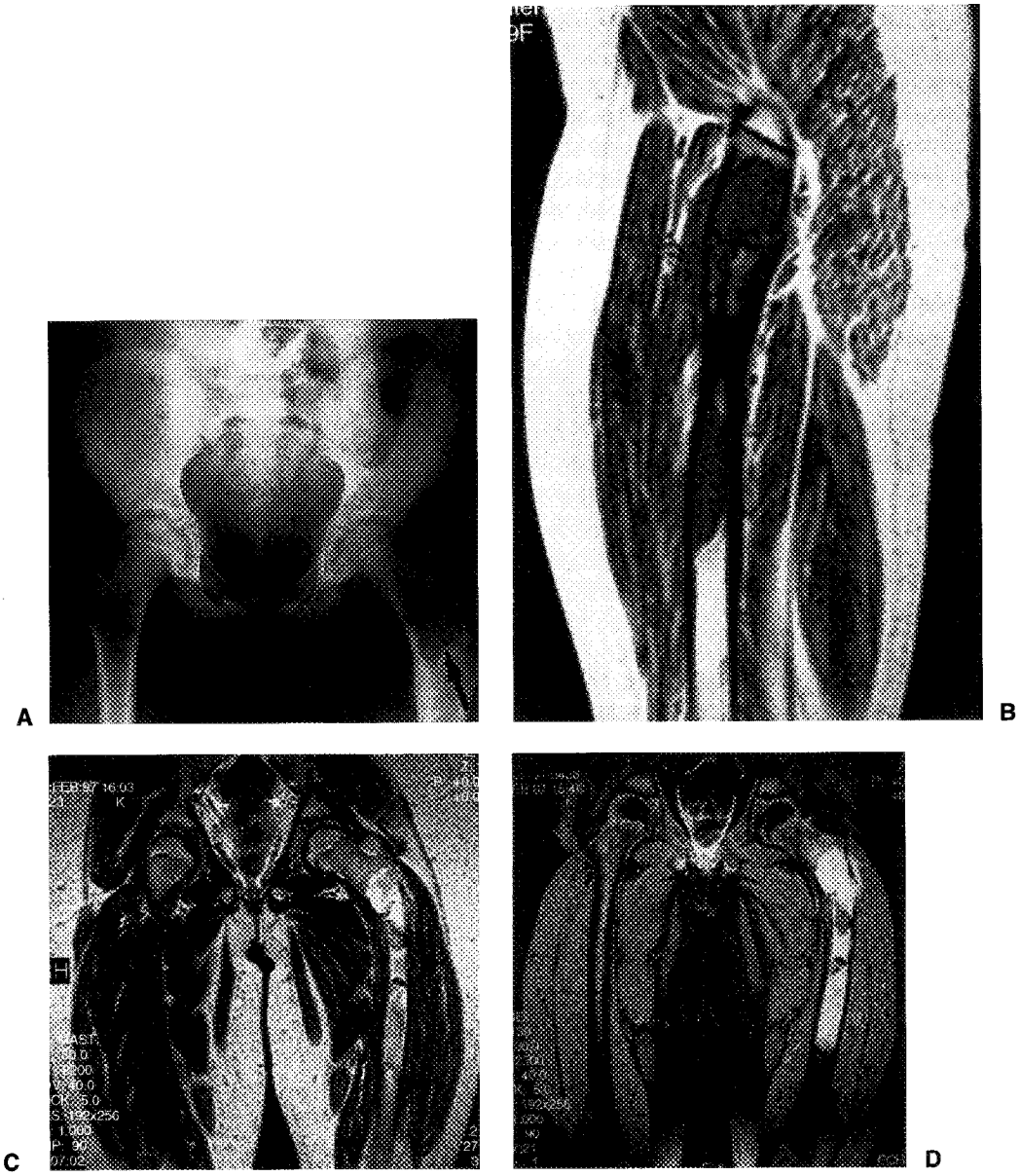


Figure 5. Fibrous dysplasia of the proximal femur in a 9-year-old girl. Anteroposterior pelvis radiograph (*A*) shows involvement of the proximal left femur (arrow) with a "shepherd's crook" deformity. Sagittal T1-weighted (500/16) MR image (*B*) shows the lesion extending through the proximal femur with a signal intensity similar to that of skeletal muscle. Coronal T2-weighted (2200/80) MR image *(C)* shows the lesion to have an intermediate signal intensity similar to that of fat, with some areas showing a signal intensity greater than that of fat. Corresponding STIR image (*D*, 2300/30/130) shows the lesion to have a high signal intensity.

Initial reports of the magnetic resonance (MR) imaging findings in FD described it as having decreased signal intensity on all MR images.[21] However, greater experience with this entity has shown that lesions demonstrate a decreased signal on T1-weighted spin echo (SE) images and variable signal intensity on T2-weighted images.[18,22] This variable appearance on T2-weighted images ranges from a signal intensity greater than that of fat (approximately 67% of cases), to similar fat or skeletal muscle in the remaining cases (Fig. 5).[18,22] Lesions tend to be relatively homogeneous unless complicated by fracture or secondary aneurysmal bone cyst. Lesions with sclerotic margins on radiographs reveal a perilesional hypointense rind on T1- and T2-weighted MR images.[22] An additional benefit of MR imaging, in contrast to CT, is that it allows sagittal and coronal imaging, which are the most sensitive radiologic methods of determining the true extent of bone involvement.[18]

COMPLICATIONS

Fibrous dysplasia may rarely undergo malignant transformation, with a reported prevalence of

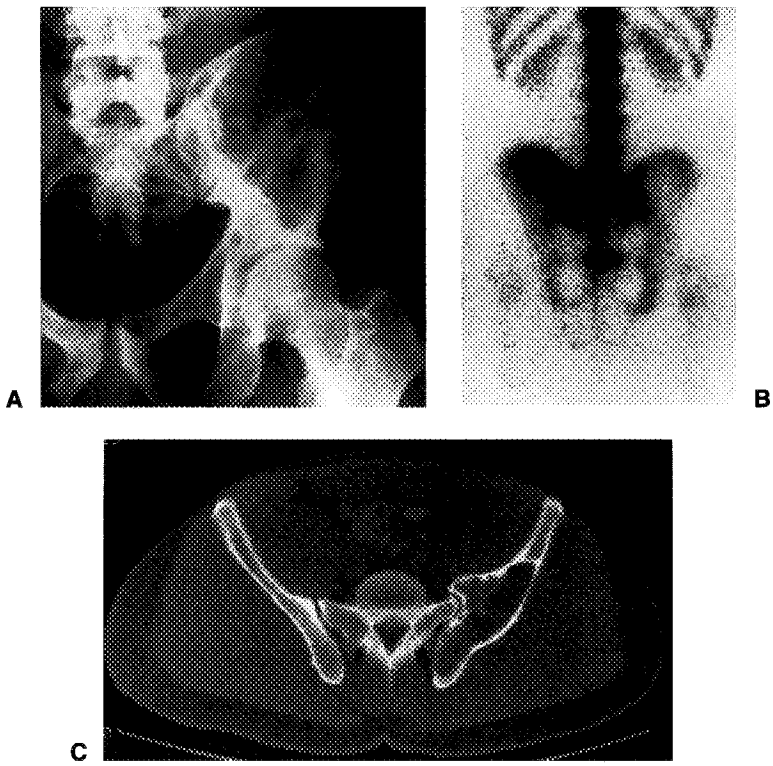


Figure 6. Fibrous dysplasia in a 23-year-old man. Anteroposterior pelvis radiograph (*A*) shows a large lesion in the left ilium. There is an expanded remodeled contour to the bone with a trabeculated appearance. No mineralized matrix is seen. Posterior delayed image from bone scintigraphy (*B*) shows markedly increased focal tracer accumulation in the lesion. CT (*C*) displayed on bone window shows the lesion to better advantage. CT identified scant mineralized matrix within the lesion (arrowhead).

0.5%.[2,23] Patients with lesions having sarcomatous change usually complain of increasing or new pain or development of a soft tissue mass. Malignant transformation should be suspected when a rapid change in the radiologic appearance, or cortical destruction of a lesion is noted on serial examinations. However, caution should be exercised in that intralesional hemorrhage and secondary aneurysmal bone cyst formation may simulate malignancy with heterogenous signal intensity on MR imaging within bone and prominent expansion. However, the surrounding soft tissue should be unaffected unless fracture has occurred as opposed to a mass in cases with malignant transformation (Fig. 7).

The most common malignancy identified in patients with sarcomatous transformation of FD is osteosarcoma, followed by fibrosarcoma or malignant fibrous histiocytoma and chondrosarcoma.[23,24] Malignant transformation is more common in patients with polyostotic disease, but it can also complicate monostotic FD. Interestingly, approximately 30% of those patients so afflicted have a history of prior radiation therapy.[24]

NATURAL HISTORY

Both monostotic and polyostotic FD usually become quiescent at puberty, although progressive deformity may be seen (Fig. 4).[25] In severe cases, there can be significant morbidity (Fig. 8). Patients with limited involvement have a more favorable prognosis, and monostotic disease usually does not progress to polyostotic disease. In most cases the size and number of skeletal lesions do not increase.[26]

FIBROXANTHOMA

Fibroxanthoma, nonossifying fibroma (NOF), fibrous cortical defect (FCD), and benign fibrous histiocytoma (BFH) are commonly used interchangeably to describe histologically identical benign fibrous neoplasms in the metaphysis of growing bones.[27–37] Controversy over the terminology and etiology of these lesions has been evident in the radiology and pathology literature since Lichtenstein and Jaffe noted the lesion in 1942. Jaffe stated that persistent FCDs progress to NOFs.[30] The historical division between FCD and NOF has been defined by size and natural history: FCDs are small metaphyseal cortical defects that disappear spontaneously (most common) whereas NOFs persist over time and may demonstrate interval growth into adulthood. We prefer the unifying term *fibroxan-*

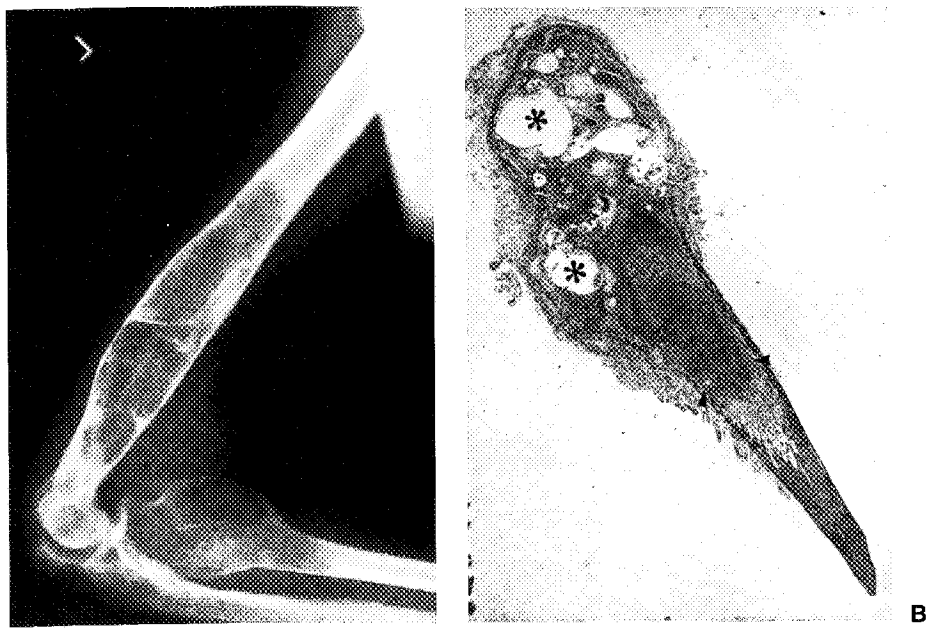


Figure 7. Polyostotic fibrous dysplasia with secondary aneurysmal bone cyst formation in a 26-year-old man. Lateral humerus and elbow radiograph (*A*) shows trabeculated lesions in the distal humerus and proximal radius, with the latter lesion revealing prominent expansile remodeling. The radial lesion was symptomatic and had increased in size. Coronal macrosection (*B*, hematoxylin and eosin) shows extensive hemorrhage (*) within the lesion (secondary aneurysmal bone cyst formation). Changes typical of fibrous dysplasia are seen in the more distal radial shaft (arrowheads).

thoma as opposed to *NOF* because it more accurately reflects the underlying pathology (spindle-shaped fibroblasts, scattered giant cells, and foam or xanthoma cells).[29]

Pathologically, the lesions are very cellular with a predominance of spindle-shaped fibroblasts oriented in a cartwheel or storiform pattern (Fig. 2C).[28,29,36–46] Variable amounts of osteoclast-like multinucleated giant cells (usually predominate in the fibrous regions and absent in the xanthoma areas) and areas with prominent xanthomatous tissue are also present with only small amounts of collagen. Abundant hemosiderin in the cytoplasm of the fibroblast cells/histiocytic round cells may also be apparent.[28,37]

Figure 8. Severe polyostotic fibrous dysplasia in 14-year-old boy. Pelvis radiograph shows marked skeletal involvement.

CLINICAL CHARACTERISTICS

Fibroxanthoma is the most common benign bone tumor, typically occurring in the developing skeleton during childhood and adolescence (age range 3 to 42 years, 70% in teenagers).[33] Lesions in patients older than 25 years old have been termed BFH, and these are more commonly symptomatic and frequently show medullary extension.[28,33] There is a slight male predominance (2 to 1). Common sites comprising 80% of lesions include the metaphyses of the distal femoral and distal or proximal tibia. Lesions about the knee, usually at the posteromedial surface, account for 55% of cases. Fibular lesions constitute 10% and are usually in the medullary canal.[2] Fibroxanthomas are frequently solitary but may be multiple, especially in the lower extremity.[34,35] Moser et al reported 72 cases of multiple fibroxanthomas, categorizing them as either clustered lesions about a joint (knee most common), nonclustered lesions at opposite ends of the same bone, coalescent lesions, or emergent fibroxanthomas (development of new lesion in a previously unaffected site).[34] Neurofibromatosis can occasionally (5%) be seen in association with multiple fibroxanthomas.[34,36,38] Café-au-lait spots in associa-

tion with multiple nonossifying fibroma, usually unilateral but occasionally bilateral, without other stigmata of neurofibromatosis constitute the Jaffe-Campanacci syndrome.[30,39,40,41] Other anomalies associated with this syndrome include mental retardation, hypogonadism, cryptorchidism, and ocular and cardiovascular abnormalities.

Clinically, patients are either asymptomatic with incidentally noted lesions or present with pain and pathologic fracture when lesions become large enough to compromise bone strength.[42] Mild pain may be secondary to nondetected fractures.

RADIOLOGIC FEATURES

Imaging features are usually pathognomonic.[27,28,32,34,37,43–46] An eccentric, ovoid, osteolytic lesion of the metaphysis (or diametaphysis) arising close to the physeal plate, with a scalloped contour and well-demarcated sclerotic margin, is characteristic (Figs. 9, 10). Medullary involvement occurs particularly in large lesions or in thin tubular bones like the fibula (Fig. 10A). Typically slow growing, variations in size and density are noted secondary to interval growth and the natural resolution with new bone filling in the original lucent defect over time. Larger lesions may demonstrate a multiloculated or septated bubbly appearance with slight expansile remodeling. It is this latter spectrum of appearances that can mimic a more aggressive neoplasm if the observer is not aware of these variations.[44] Periosteal reaction is noted only in those lesions with pathologic fracture.

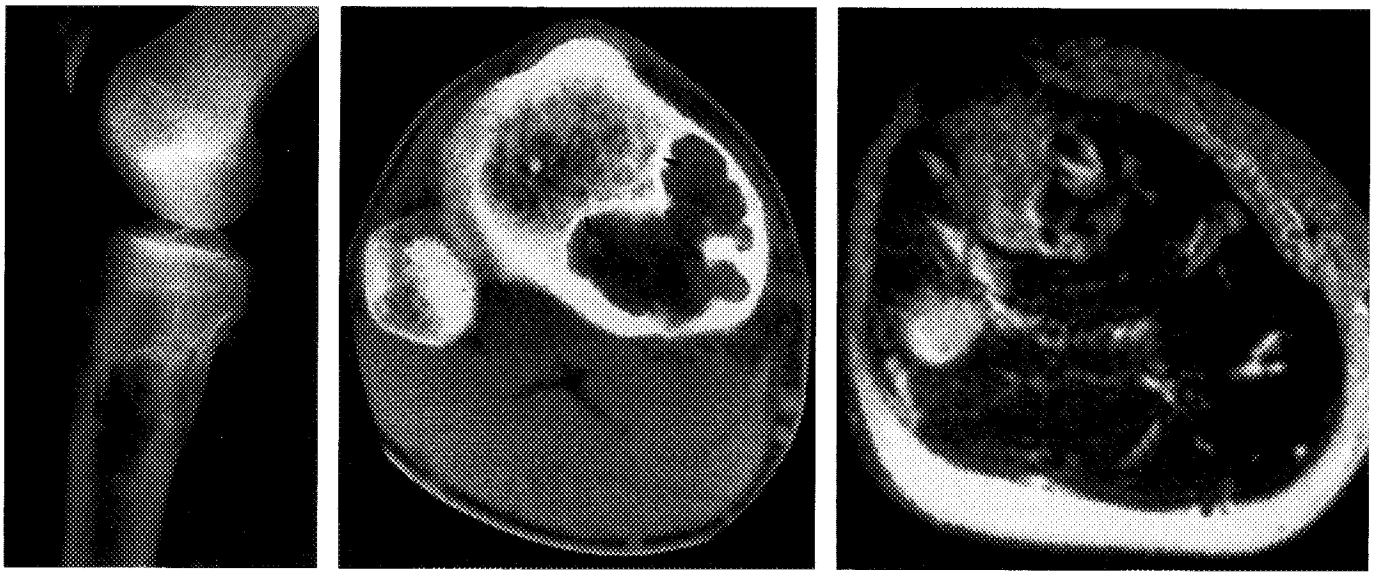
Advanced imaging is usually not indicated. CT appearance is similar to radiographs; however, these lesions commonly demonstrate soft tissue attenuation within the lesion (Fig. 9B). Kransdorf et al described a characteristic low signal appearance (compared with skeletal muscle) on both T1 and T2 MR sequences thought to represent hemosiderin deposits or large amounts of collagen (Fig. 9C).[29,45] Jee et al noted internal septation in 95% of cases, correlating with areas of increased trabeculation.[45] Postgadolinium MR studies often demonstrate intense contrast enhancement. Increased activity (mild) is commonly noted on bone scintigraphy.[33,43]

TREATMENT AND PROGNOSIS

Curettage and bone graft are only rarely necessary, in patients where the diagnosis is in doubt or to prevent pathologic fracture in large lesions (greater than 3 cm or affecting >50% of the bone width) involving weight-bearing bone, particularly the distal tibia.[28,29,47]

CORTICAL DESMOID

The cortical desmoid is a common benign reactive fibrous or fibro-osseous lesion of children and adolescents that should not be misinterpreted as indicative of a more aggressive lesion (particularly osteosarcoma). Review of the literature since Sontag and Pyle first described a "metaphyseal cyst" to the present is confusing, with numerous



A B C

Figure 9. Incidental fibroxanthoma detected within the left tibia of a 14-year-old male. Lateral knee radiograph (*A*) depicts a characteristic trabeculated lytic metadiaphyseal lesion abutting the proximal epiphyseal plate with the sclerotic margins. CT (*B*) and axial T2-weighted (2000/90) MR image (*C*) demonstrates an intracortical lobulated lesion with well-defined, intact, sclerotic margins. There is soft tissue attenuation on CT and sclerotic inner margin representing endosteum (arrowheads). The lesion is predominantly low signal on MR imaging due to high collagen content.

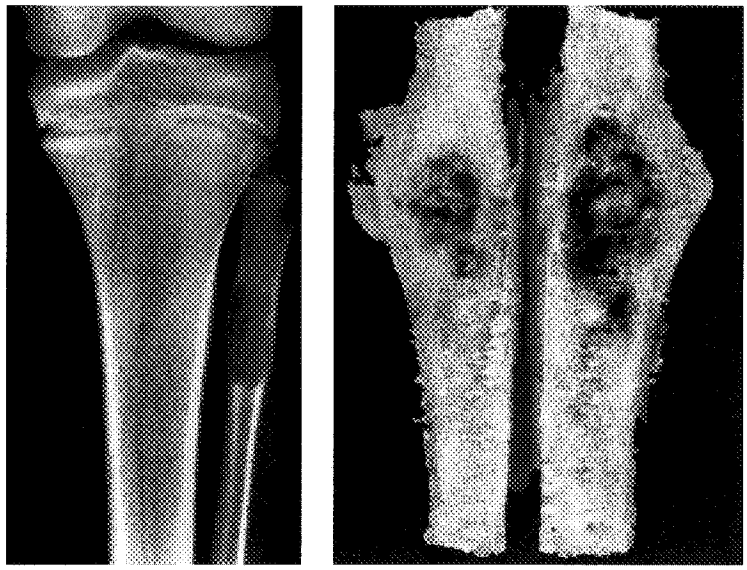


Figure 10. Thirteen-year-old male with mild pain within the left lower leg. Anteroposterior radiograph of the proximal left tibia and fibula (*A*) demonstrates a septated, well-defined lytic lesion consistent with fibroxanthoma within the proximal fibular diaphysis. The lesion expands the medullary canal in this small tubular bone, giving rise to a "central" appearance. Color photograph (*B*) of the sectioned gross specimen depicts the typical grayish yellow tissue representing fibroxanthomatous tissue and collagen.

pseudonyms (cortical avulsive irregularity syndrome, distal femoral cortical irregularity, fibrous cortical defect, subperiosteal or periosteal desmoid, and a variant of periostitis ossificans) and various proposed etiologies.[48–59] The currently used term is *cortical avulsive injury*. Johnson et al coined the term *cortical desmoid* in 1968 at the Armed Forces Institute of Pathology in their review of 75 cases and described it as a defect along the medial extension of the linea aspera in asymptomatic active adolescent boys.[51] Resnick and Greenway concluded that the cortical desmoid occurs at the site of attachment of extensor tendinous fibers of the adductor magnus muscle secondary to stress, whereas the cystic "excavation" variant occurs in children and may persist in adults as a stress-related event at the osseous site of the attachment of the medial head of the gastrocnemius lateral to the medial supracondylar line and adductor tubercle 1 cm above the superior limit to the medial condyle.[59] The pathogenesis is explained as a microavulsion followed by fibroblastic response that continues to repeat in a cyclic pattern.[53,57]

Pathologically, these regions have a nonspecific fibrovascular appearance with intermixed spicules of bone.[28] Microscopically, Johnson first described areas of cortical erosion lined with osteoclasts and filled with proliferating subperiosteal connective fibrous tissues (fibroblasts) and small fragments of resorbing bone with osteocytes in lacunar spaces.[51]

The histology is consistent with a reactive process rather than a neoplastic process. However, for the less experienced pathologist, confusion with osteosarcoma has occurred and should emphasize the need for radiologic correlation.

CLINICAL CHARACTERISTICS

These benign lesions are most commonly seen within the left femur (2 to 1), with a slight predominance in boys (11% versus 3.6% of girls), between ages 10 to 15 years (range 3 to 20 years).[27,52,60] More recently, similar lesions have been described in the humerus at the insertion sites of other muscles, including the pectoralis major and deltoid muscles.[61–63] Bilateral lesions are demonstrated in 35% of cases.[27,51,52,55,58] Patients are typically asymptomatic, with lesions detected incidentally on radiographs performed for other reasons, although mild pain has been reported.[28,63–66] Lesions may persist into adulthood.

RADIOLOGIC FEATURES

Radiographs reveal radiolucent areas of cortical irregularity or saucerization, 1 to 3 cm in size, within the posteromedial aspect of the distal femur, characteristically along the medial supracondylar ridge, proximal to the adductor tubercle (Fig. 11).[27,58,59] Margins may be partially well defined; however, areas of irregularity are often seen and periosteal new bone may occur in response to the stress reaction at the lesion. There is no associated soft tissue mass, although soft tissue swelling can be present during persistent stress. Lesions are best

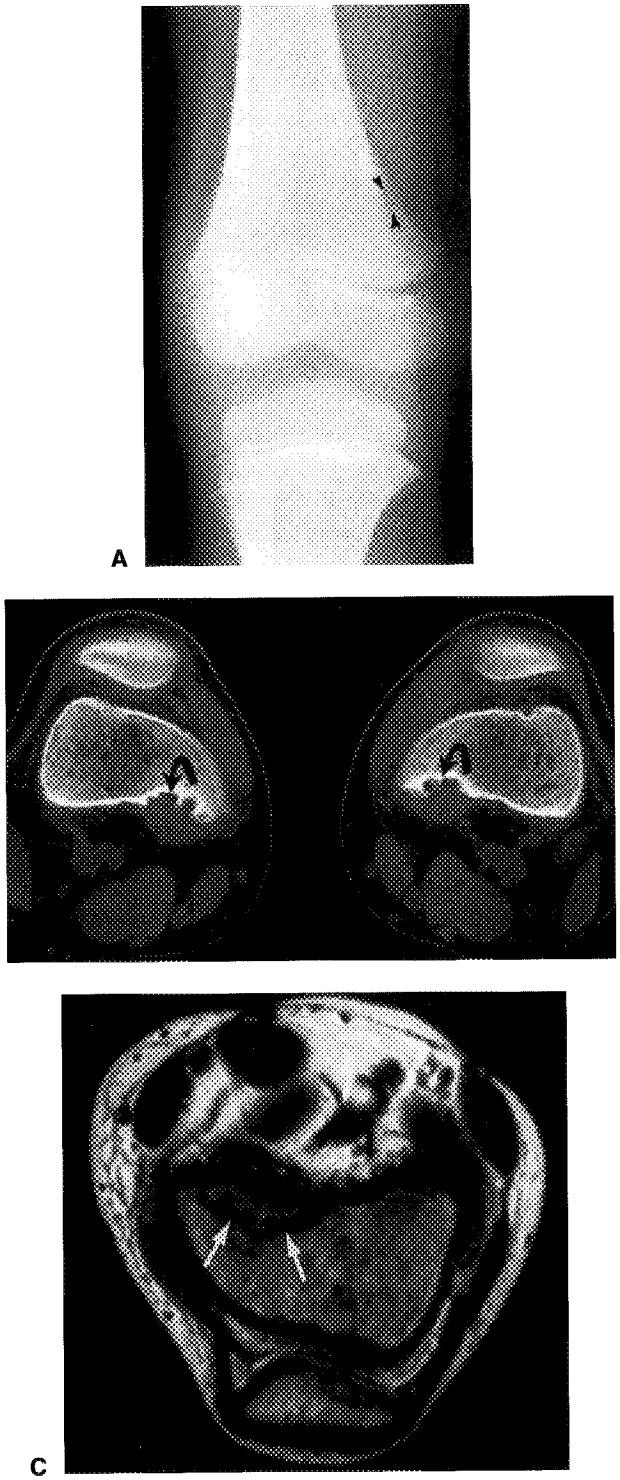


Figure 11. Twelve-year-old female with bilateral knee pain. Oblique knee radiograph (*A*) shows a small lytic lesion in the distal medial femoral metaphysis (arrowheads). CT (*B*) of both distal femoral metaphysis shows bilateral posteromedial cortical defects with irregular concave sclerotic medullary borders and soft tissue attenuation centrally (curved arrows). Axial T1-weighted MR image (*C*, 500/20) depicts the characteristic posteriomedial location with low-signal, well-defined border and intermediate signal centrally (arrows).

seen on oblique radiographs of the distal femur.[44,56,58] Scintigraphy usually demonstrates no increased uptake at the site, although this could be masked by the lesion's proximity to the distal femoral epiphyseal plate in children.[60,67] Some may show increased uptake secondary to reactive stress.

CT or MR imaging may be useful to obviate biopsy in the rare case where radiographs are not diagnostic (Fig 11).[60,64–66] Differentiation from a more aggressive process is made by the characteristic lack of soft tissue mass and common presence of bilaterally symmetric lesions. Lesions are typically low signal intensity on T1-weighted and increased signal (related to fibrovascular reparative tissue and cartilage) on T2-weighted MR images with a rim of low signal intensity corresponding to the sclerotic radiographic margin.[60] Although useful, MR imaging can sometimes be confusing, showing reactive edema within marrow and soft tissue and contrast enhancement at times suggesting a more aggressive process.

TREATMENT AND PROGNOSIS

No treatment is required other than supportive care, limiting activity if the lesion is associated with pain. As stated previously, lesions may persist into adulthood.

DESMOPLASTIC FIBROMA

Desmoplastic fibroma (DF) is a rare benign fibrous neoplasm of bone that Jaffe originally described in 1958.[30] Typically nonmetastasizing but often locally aggressive, DF is the osseous analog of the extraabdominal desmoid tumor of soft tissue, characterized pathologically by sparce intersecting spindle-shaped fibroblasts and myofibroblasts within an abundant collagenous stroma.[44,68–73] Lack of both pleomorphism and a herring bone pattern helps to differentiate this lesion from malignant spindle cell lesions (particularly low-grade fibrosarcoma) and avoid unnecessary aggressive treatment.[28,30,74]

CLINICAL CHARACTERISTICS

The incidence of DF is reported as 0.06% of all bone tumors and 0.3% of all benign bone tumors.[30,70] Lesions are most common in the second and third decades of life, with 75% of patients less than 30 years old (mean 21 years; range 20 months to 71 years).[44,69,70,72,75] There is no sex predilection, and symptoms are nonspecific pain and/or swelling of weeks to months duration.

The mandible (26%), central metaphysis (proximal or distal) of long tubular bones (56%) (femur, humerus, tibia and radius), and innominate

bone (14%) are the most commonly affected sites. Less commonly, lesions of the maxilla, scapula, vertebra, ulna, fibula, clavicle, and ribs have been reported, with rare cases involving the small bones of the hands and feet and sternum.[28,76] There are also rare reports of FD and DF coexisting.[77,78]

RADIOLOGIC FEATURES

Desmoplastic fibromas are centrally located, expansile, osteolytic lesions with a coarse "soap bubble" or "honeycomb" appearance secondary to irregular delicate trabeculations traversing the lytic areas.[44,68,74] Typically, they are solitary and oval, with the largest dimension aligned with the long axis of the host bone (Fig. 12).[69] Endosteal scalloping, expansile remodeling, and a thinned cortex with a narrow zone of transition caused by a sclerotic rim is typical without evidence of mineralized matrix. Periosteal reaction is usually absent or minimal unless associated with pathologic fracture.[69] However, occasionally, more aggressive radiographic features, such as permeative bone destruction, cortical erosion, local soft tissue invasion or mass, and mimicking malignancy, are seen.[44,74]

Bone scintigraphy can demonstrate increased activity; however, very large lesions may have a photopenic center.[70] CT and MR imaging assess the continuity of the cortex and/or presence of soft tissue mass and extent of invasion.[74,76] CT attenuation is nonspecific and similar to muscle. MR imaging signal intensity is often low on both T1- and T2-weighted images because of the diffuse collagenized tissue components (Fig. 12).

TREATMENT AND PROGNOSIS

Wide en bloc resection is often curative.[44,68–82] In areas of major functional deficit (i.e., knee), intralesional curettage and bone grafting may be attempted.[70] However, recurrence following conservative surgery is common (up to 40%) and long-term evaluation is required.[72,74] There is only one report of metastasis or sarcomatous recurrence in the literature in which a mandibular desmoplastic fibroma recurred as a grade 2 fibrosarcoma with pulmonary metastasis.[79,80]

MALIGNANT FIBROUS HISTIOCYTOMA AND FIBROSARCOMA OF BONE

Malignant fibrous histiocytoma (MFH) is a pleomorphic sarcoma that in combination with fibrosarcoma (composed exclusively of fibroblastic differentiation without mineralized matrix production) comprises 5% of all primary malignant bone tumors.[83–87] Macdonald and Budd first described fibrosarcoma in 1943 and later Phemister in 1948.[88,89] Since O'Brien and Stout's initial description of MFH in 1964 and the report of the first occurrence in bone in 1972, there has been continued controversy over its histogenesis—ranging from a histiocytic origin to the theory of differentiation into histiocytes and fibroblasts from a single primitive mesenchymal cell.[90,91] Characterized by aggressive bone destruction, cortical involvement, and a soft tissue mass, MFH of bone is much less common than the soft tissue variety. It contains both fibroblast-like and histiocyte—like elements in varying proportions, contributing to its wide variety of appearances.[28] The primary differential diagnosis is fibrosarcoma, and it is likely that many fibrosarcomas in the literature in the past were actually MFHs.

Pathologically, MFH and fibrosarcoma are distinct entities. Hemorrhagic zones and necrosis are common.[28,84] Microscopically, MFH is a diagnosis of exclusion consisting of variable proportions of fibroblastic or histiocytic characteristics. Three essential findings are as follows: (1) multiple bundles of fibroblasts in a cartwheel or storiform pattern with mitotic figures and atypia, (2) round or oval histiocytes with grooved or reniform nuclei and well-defined cytoplasmic border, and (3) pleomorphic multinucleated giant cells (osteoclastic type) with abundant cytoplasm.[28,84,92–101] Fibroblast spindle cells have greater nuclear atypia and are less uniform than those seen in fibrosarcomas. Giant cells are also more common in MFH than fibrosarcoma. Differentiation from osteosarcoma is made by the presence or absence of osteoid formation by the malignant cells.

Whereas five soft tissue subtypes of MFH are described, only the two most common, storiform-pleomorphic (50 to 60%) and myxoid (25%), types are commonly encoutered in the intraosseous version.[83,84,101] Fibrosarcomas are histologically graded from well to poorly differentiated lesions.[89,101] Microscopically, the most characteristic feature is the interlacing fascicles of the elongated fibroblastic spindle cells forming a focal herring bone pattern.[28] This is a more prominent feature in the lower-grade lesions (65%), with orderly bands and whorls of collagen as opposed to higher-grade lesions (30 to 35%) reflecting more anaplasia.

Although 70 to 80% of MFH and fibrosarcomas arise de novo, 20 to 30% arise in secondary preexisting osseous conditions.[28,44,83] Both neoplasms have been reported in association with Paget disease, osteonecrosis, radiated tissues, fibrous dysplasia, fibroxanthoma (nonossifying fibroma), enchondroma, chronic osteomyelitis, and total joint replacements.[84,92–98] Secondary MFH or fibrosar-

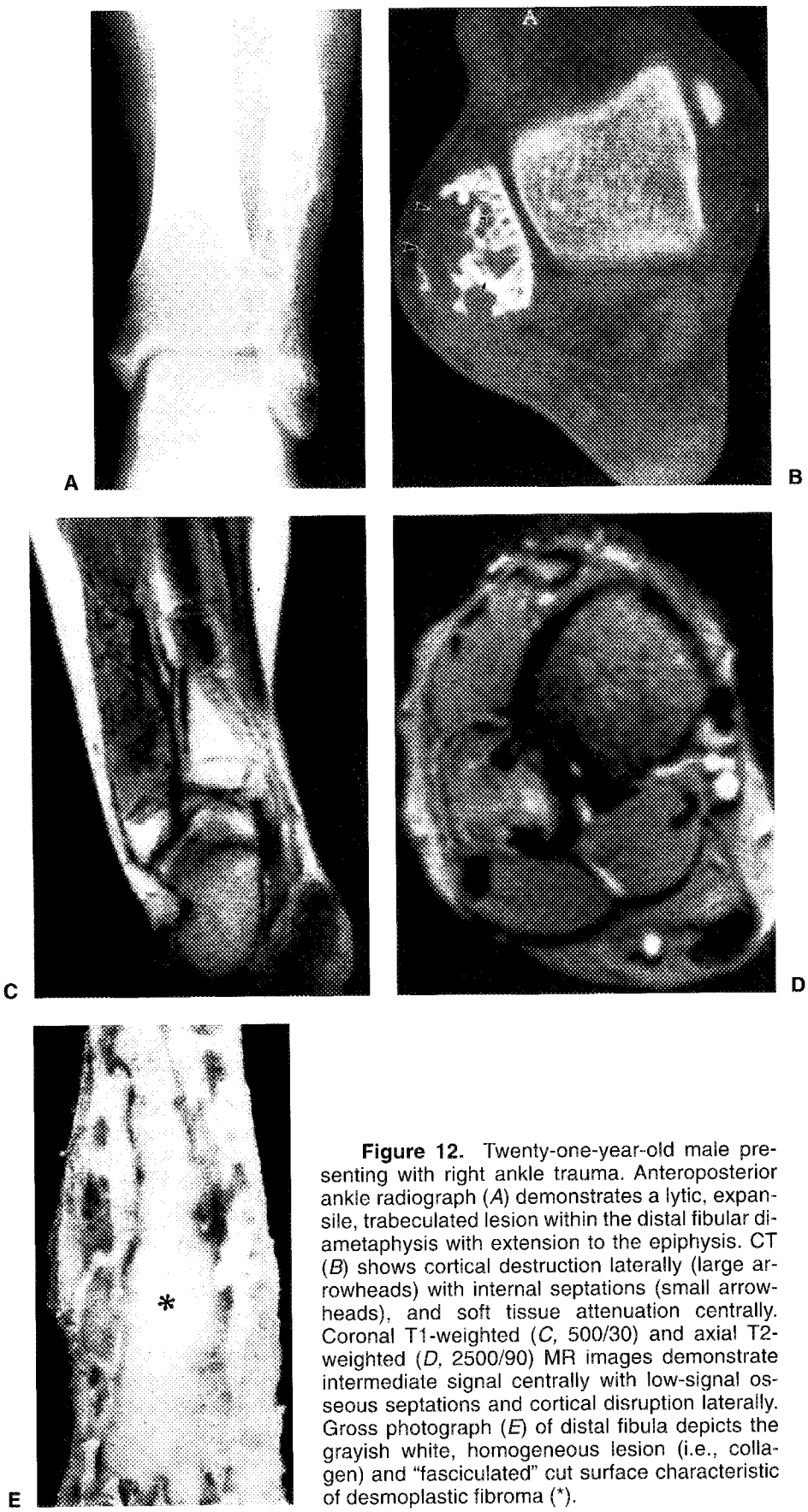


Figure 12. Twenty-one-year-old male presenting with right ankle trauma. Anteroposterior ankle radiograph (*A*) demonstrates a lytic, expansile, trabeculated lesion within the distal fibular diametaphysis with extension to the epiphysis. CT (*B*) shows cortical destruction laterally (large arrowheads) with internal septations (small arrowheads), and soft tissue attenuation centrally. Coronal T1-weighted (*C*, 500/30) and axial T2-weighted (*D*, 2500/90) MR images demonstrate intermediate signal centrally with low-signal osseous septations and cortical disruption laterally. Gross photograph (*E*) of distal fibula depicts the grayish white, homogeneous lesion (i.e., collagen) and "fasciculated" cut surface characteristic of desmoplastic fibroma (*).

coma is most frequently associated with radiation in the literature, although our personal experience suggests that fibroxanthoma (nonossifying fibroma) is the most frequent. Radiation doses greater than 30 Gy and a latent period of at least 3 to 4 years is typical with secondary MFH of bone.[84,92,93]

CLINICAL CHARACTERISTICS

MFH most commonly occurs in the appendicular skeleton, with 75% affecting the long bones (distal femur, proximal tibia, proximal femur, humerus in decreasing order of frequency).[28,83,44] The central metaphysis is affected in 90% of cases, although diaphyseal and epiphyseal extension also occurs.[100] The pelvis, spine, or ribs are involved in 21% of cases. Nonspecific pain, swelling, or an enlarging mass is common, and 20% present with a pathologic fracture.[44,83] Age range affected is 6 to 80 years, with a peak in the fourth decade and there is a male predominance (1.5 to 1).[84,100,101] Lesions are solitary with rare reports of multifocal MFH or fibrosarcomas (less than 1%).[28,44,88,100,102]

Fibrosarcoma affects the long bones in 70% of cases (50% in the lower extremity, particularly about the knee). The most common location is the distal femoral metaphysis (40%), followed by the proximal tibia (16%).[42,44,89] Epiphyseal extension (but not to subchondral bone) is not infrequent, and purely diaphyseal lesions are less common (7%).[44,99–103] Other locations include the proximal humerus (10%), pelvis (13%), and rarely the bones of the jaw (8%, of which the mandible is the most common).[42,44,89] Fibrosarcomas are seen in a slightly younger age group than MFH, occurring predominantly in the second to seventh decades (average in the fourth decade) with equal sex predilection in most series.[42,83,100,101] Cases of a congenital form have also been reported, unlike MFH.[89,104] Nonspecific pain and swelling are the most common symptoms, and pathologic fracture is noted in 30% of cases.[88,89,99,100]

RADIOLOGIC FEATURES

The imaging appearances of MFH and fibrosarcoma are indistinguishable and are therefore discussed together. These lesions, in our experience, most frequently demonstrate geographic bone destruction with a wide zone of transition (Fig. 13A). Radiographs not infrequently show focal areas of narrow transition zone or even sclerosis. Focal areas of cortical penetration with soft tissue mass are invariably present by CT or MR imaging but may be difficult to appreciate on radiographs (suggesting a less aggressive process). However, the spectrum of bone destruction pattern with these lesions is wide and moth eaten or permeative osteolysis may also be seen.[44,83,101–105] These malignancies are typically located within the metadiaphysis or metaepiphysis but, unlike giant cell tumor, do not extend to the articular surface. Only 10% occur within the diaphysis alone, typically eccentric in location and with a soft tissue mass.[83] Periosteal reaction is unusual, in our experience, in cases of MFH and fibrosarcoma, unless associated with pathologic fracture.[42,44,89,104] However, Taconis et al reported lamellar periosteal formation in 73% of fibrosarcomas in their study.[100]

As with other neoplasms, CT and MR imaging are useful for preoperative staging and surgical planning, with the latter modality superior in defining marrow and soft tissue extent.[83,89,105–107] Typically there is no matrix mineralization, although small areas (best seen on CT) can be seen, making exclusion of osteosarcoma (younger patients) or chondrosarcoma (usually demonstrates a lobular growth pattern not seen in MFH or fibrosarcoma) difficult (Fig. 13B).[44,83,84,106] The nonmineralized tissue has a nonspecific soft tissue attenuation on CT (Fig. 13B).[83,89,105,107] Lesions are typically lower than or isointense to muscle on T1-weighted and are of heterogeneous high signal on T2-weighted MR images (Fig. 13C). However, low to intermediate signal on long time to return (TR) images may also be apparent with higher collagen content lesions. Areas of central necrosis or hemorrhage may be seen, creating peripheral and nodular enhancement after contrast administration (Fig. 13D).[44,83,105,107,108] Both bone scintigraphy and gallium scans show increased activity within the osseous extent and are useful in delineating metastasis.[109] Scintigraphy may also demonstrate peripheral increased activity with extraosseous extension in fibrosarcoma.[44,88] Photopenic lesions have been described.[110]

TREATMENT AND PROGNOSIS

The best prognosis for both MFH and fibrosarcoma is with wide en bloc resection and limb salvage techniques in combination with neoadjuvant chemotherapy.[83,111–112] Five-year survival for high-grade fibrosarcomas is 34%.[28,42,111] MFH and fibrosarcoma arising in preexisting osseous abnormalities have a worse prognosis than the de novo variant (i.e., 10% ten-year survival reported for secondary fibrosarcoma).[42] Recent studies have concluded that neoadjuvant chemotherapy in addition to surgery significantly improved prognosis of MFH in bone.[112] Inoperable lesions receive chemotherapy and radiation alone. Radiation is also often employed postoperatively. Local recurrence is common in high-grade lesions (24% for fibrosarcoma) following wide or radical surgical procedures, secondary to their infiltrative nature. MFH and fibrosarcoma most frequently metastasize to lung and

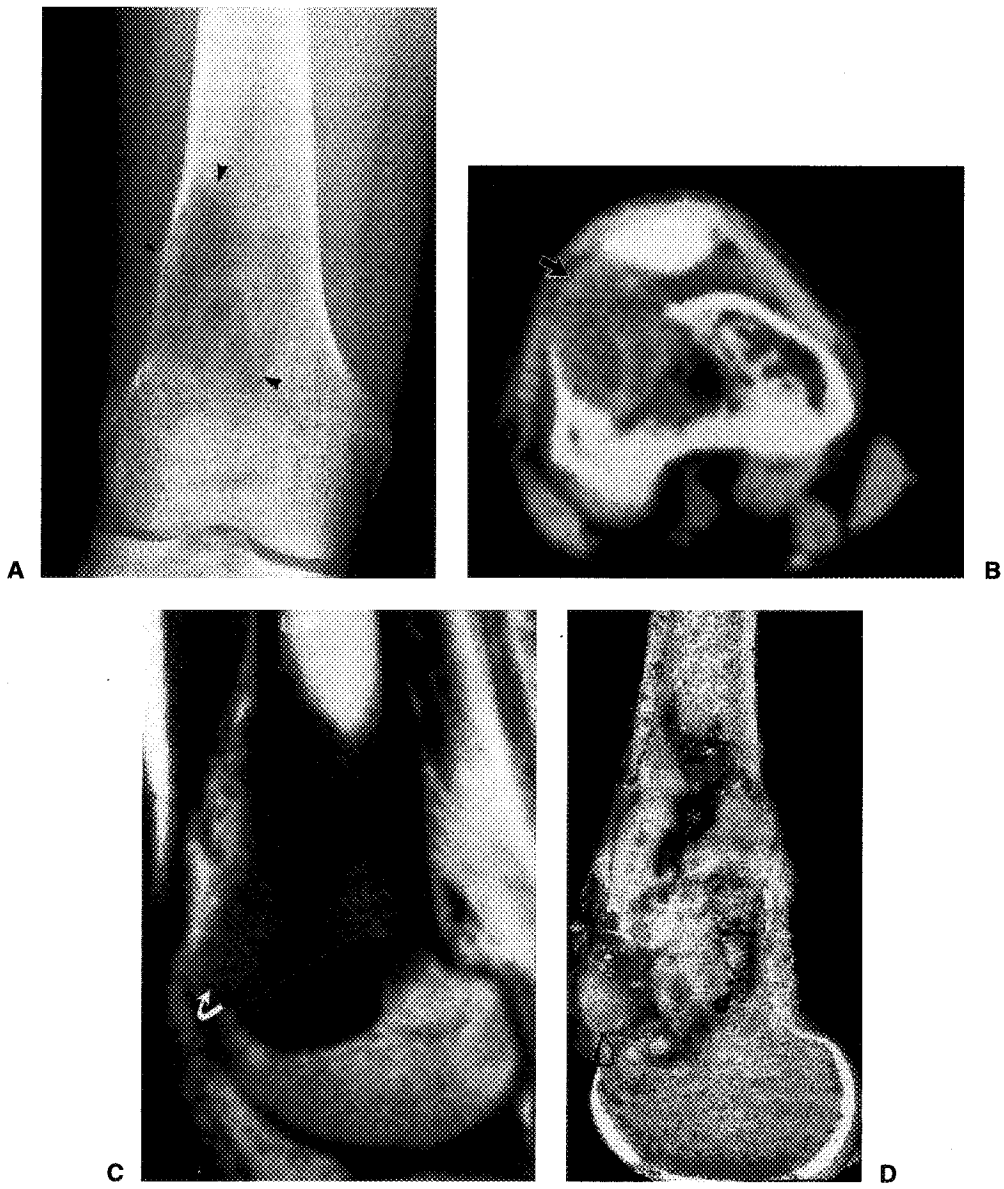


Figure 13. Forty-four-year-old male with local pain within the right knee. Anteroposterior distal femur radiograph (*A*) shows an ill-defined aggressive slightly eccentric metadiaphyseal lesion (large arrowheads) with focal periosteal reaction (small arrowheads). CT (*B*) demonstrates soft tissue attenuation of the intramedullary lesion with destruction of the cortex and soft tissue extension (arrow). No internal matrix is present. Sagittal T1-weighted (500/20) MR image (*C*) reveals a homogeneous low-signal-intensity lesion within the distal metadiaphysis extending beyond the cortical margin (curved arrow). Photograph of sagittal gross specimen (*D*) shows a heterogeneous yellow/brown lesion, "rubbery" in appearance, with central regions of hemorrhage and necrosis (*) and soft tissue extension (open arrow) identical to imaging apperance.

bone. Regional lymph node involvement is more common in MFH.[89,103]

SUMMARY

Whereas the spectrum of primary fibrous tumors of bone all contain similar histologic elements, the clinical and imaging characteristics described herein can help distinguish these lesions from one another and from other entities. The radiologic appearance of fibrous dysplasia, fibroxanthoma (nonossifying fibroma), and cortical desmoid is usually pathognomonic, obviating the need for biopsy in the vast majority of lesions. Indeed, biopsy may be confused pathologically with a more aggressive lesion if not correlated with radiologic features. Advanced techniques (CT and MR imaging) are important in helping to delineate desmoplastic fibroma, MFH, and fibrosarcoma extent both initially and after surgical resection to evaluate for recurrence. Recognition of the

disease spectrum, including treatment options and prognosis, reviewed in this article provides insight to the role of the radiologist in guiding patient management.

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Army, Navy, or Department of Defense.

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